have come from the mistaken notion that an anticyclone brought down air from the upper strata, and therefore ought to be cold. The descending air does occur, but the temperature during an anticyclone a few hundred feet high is unduly warm." In the April number Dr. J. Hann points out the fact that it is not the absolute height of the barometer that is determinative in locating anticyclones, but rather the relative height of the barometer compared with that of the surrounding districts. He maintains that the center of an anticyclonic area is cold in winter, "a focus of cold"—an opinion supported by the investigations of Hildebrandsson on temperatures in cyclones and anticyclones. "The cold arises in winter in anticyclonic regions as a result of radiation favored, in a high degree, by the clear skies and the dry air of the anticyclonic center. One can say definitely that the cooling of the earth in the winter half-year is accomplished mainly in the anticyclonic areas of the land surface. Nocturnal radiation is very intense in the dry air, especially when the surface of the ground is covered with snow." The extremes of the winter months in central Europe show no constant relation to the variations of pressure in central Europe itself, as the "focus of cold" is usually at the center of a persistent continental anticyclone to the northeast. Only in exceptional cases is central Europe itself the seat of this center, and when it is, abnormally cold weather is experienced. As the British Isles usually remain on the western side of the European anticyclone, and thus have southerly and southeasterly winds with high barometer, it follows that high temperatures quite often accompany the high barometer. At the same time, however, it is cold on the continent in the center of the European anticyclone.

ANDREW H. PALMER
BLUE HILL OBSERVATORY,
April 25, 1911

THE SOIL, A LIVING THING

FOR many years the fertility of the soil was sought in the chemical substances which analysis proved to be essential to plants and which could be exhausted from the soil by the continual growth of a single crop upon it. To restore the fertility of the soil, it was necessary only to restore the ingredients necessary to keep a plant in a productive condition. Fertilizers were applied which were known to contain the most important materials of plant food and in an available form. Even to-day, there are opposing camps of plant physiologists. One set holds to the principles, first clearly enunciated by Liebig, that the chemical condition of the soil is the most influential factor in the productivity of the garden, or farm. The other group consider that the physical condition of the soil influences the tilth. This school teaches that all agricultural soils contain sufficient quantities of the essential mineral plant foods for many years to come. Recently a more advanced position has been taken by some students of the soil, when they claim that the loss of fertility of many long cropped soils is due to the accumulation of toxic bodies, the accumulated excreta of plants that may have been grown without proper rotation. The true theory of soil fertility will probably be found to be one which will combine all of these theories with another one, which I believe must also be considered in reaching a satisfactory conclusion as to the relation existing between crops and the soil in which they grow.

The theory is one which considers that the soil is a living thing apart from its chemical or physical structure, that in the reaction between the living soil and the growing plant is the true explanation of soil fertility. A fertile soil is a live one. An infertile soil is a dead one. Contrast the soil which is filled with organic matter (humus) and in which numberless fungous, bacterial and protozoan organisms are at work with a mass of clay or sand without such organic material and associated living organisms. The one soil is fertile, because the organisms in the soil react favorably upon each other, the other soil is infertile, because the organisms present in this soil are antagonistic. Recent investigation has pointed the way along which future research on soils must proceed and some of this instructive work may be reviewed here briefly and in a sequence which suggests the orderly manner in which effect follows cause.

Harter[1] in a paper entitled the "Starch Content of Leaves dropped in Autumn" has shown that the well-established belief that autumn leaves contain very little carbohydrate in the form of starch and sugar is erroneous, for during the summer of 1909, he undertook to trace the change taking place in the amount of starch formed in the leaves of *Liquidambar styraciflua* at different periods, viz., August 17, September 15, October 23 and October 28. On October 28, the leaves were collected which had fallen recently from the tree. The starch in the leaves collected at the different dates was determined quantitatively and was found to be as follows: August 17, 10.91 per cent.; September 15, 10.33 per cent.; October 23, 11.47 per cent. and October 28, 10.79 per cent., based on the dry weight of the material. Since so much starch was found in the fallen leaves of the sweet gum similar material was collected from several other plants and the starch determined as above. The amount of substances in the leaves capable of reducing the copper in Fehling's solution, as determined by the above method, are shown in the table:

	Per Cent
Liquidambar styraciflua	10.79
Gingko biloba	6.32
Platanus orientalis	11.84
Platanus occidentalis	9.89
Styrax americana	5.91
Magnolia obovata	7.19
Quercus pedunculata	14.54
Elæagnus umbellata	10.24

The thought suggested to me after reading the results of Harter's work was one which considered the final disposition of the starch in the fallen leaves. Is this starch disintegrated, or is it changed into a form by which it can be utilized by the roots of forest plants and by the organisms of the soil? To answer this question, I would call attention to the studies of a graduate student of mine, who in a recent piece of work on "Bacteria and other Fungi in Relation to the Soil" has discovered the ultimate destiny of this carbohydrate material. Dr. Rivas[2] by a detailed analysis of the bacterial content of virgin forest soils has shown that the largest number of bacteria are found during October, and the least number during the winter months. He finds that the forest soils contain bacteria which produce enzymes capable of fermenting the carbohydrates, as shown in the following tabulation of his results, which shows the relative proportion of the different ferments produced by the species isolated.

	Per Cent.
1. Diastatic ferment acting on starch, found in 24 cultures	60.0
2. Inverting ferments, inverting starch or saccharose into glucose found in 29 cultures	72.5
(A) Inverting starch into glucose found in 22 cultures	55.0
(B) Inverting saccharose into glucose found in 14 cultures	35.5

The presence of these organisms in the soil clearly points to the fact not previously considered in the study of forest soils, that the starch found in autumn leaves can be converted directly by such soil organisms into glucose, and it is probable that this sugar is directly absorbed by the roots of higher plants (a fact not previously suspected), either by the root hairs, or by means of the mycorhiza found abundantly on the roots of many forest trees. Such sugar is also utilized by non-chlorophylless plants, saprophytic fungi (*Agaricus*), and flowering plants (*Monotropa*), for it has long been known these plants can absorb the whole of their organic food (including the soluble carbohydrates) from the humus and that the various mycorhiza living in commensalism with the roots of phanerogams are probably of considerable importance in render-

[1] *The Plant World*, 13: 144–147, June, 1910.

[2] "Contributions from the Botanical Laboratory of the University of Pennsylvania," III., 243–274.

ing the humus available. Saida[3] has shown that the parasitic fungus *Phoma betæ* can fix nitrogen in the presence of cane sugar, as follows:

Substances Added to a Nutrient Salt Solution	Cane Sugar in Grams	Fixation of N in Milligrams
Cane sugar	5	.7393
Cane sugar	17	1.1828
Cane sugar $(+(NH_4)_2CO_3$ trace)	5	1.1828
Cane sugar $(+(NH_4)_2CO_3$ trace)	10	1.7742
Cane sugar $(+(NH_4)_2CO_3$ trace)	20	3.5484
Cane sugar $(+(NH_4)_2CO_3$ trace)	30	6.2097

More recently Ternetz[4] has isolated five endophytic mycorhizal fungi from certain Ericaceæ, all of which have been found to belong to the genus *Phoma*. Three of these organisms, *Phoma radicis oxycocci, Phoma radicis vaccinii* and *Phoma radicis andromedæ*, have shown a well-developed capacity for nitrogen fixation in culture, these three mentioned working even more economically than *Azotobacter chroococcum*, the amount of nitrogen fixation in milligrams per gram of dextrose being under the conditions of culture, respectively 22.14, 18.08, 10.92 and 10.66 for the four organisms mentioned.

With these discoveries in view, we can briefly summarize. The starch in fallen autumn leaves is converted by certain forest soil bacteria into glucose. This glucose is utilized directly by the roots of forest trees, by various saprophytic plants and by the mycorhiza, which by the aid of the glucose are enabled to fix considerable amounts of nitrogen. That the soil is the seat of other activities of as much importance to growing plants, as the above, is proved by the presence of the nitrifying and denitrifying bacteria, of the bacteria that produce the root nodules of the Leguminosæ, of such organisms as *Clostridium pastorianum, Bacillus mycoides, B. ellenbachensis, Azotobacter chroococcum, A. Vinelandii* and the hyphæ of numerous saprophytic fungi, various putrefactive bacteria, which perform their rôle in making the soil the fit habitation of the higher flowering plants, producing the tilth or "Bodengare" of the Germans. So too earthworms, insect larvæ, ants and burrowing animals assist in the task of aerating and mixing the surface layers of the soil. It is also evident that the production of toxic excretions by the roots of plants is undoubtedly a factor of importance in soil fertility. Following out a clue which the partial sterilization of the soil by chemicals or by steam gave, it was discovered that the bacteria which are useful in ammonia-making increased four-fold after such treatment, suggesting the presence in the soil of some agent which held them in check. After much painstaking study, it was discovered[5] that the soil contained a living protozoon (*Pleurotricha*), which preyed upon the useful organisms, and that the heat and chemicals either destroyed these larger unicellular animals, or inhibited their activity. It can be said, therefore, that the fertility of the soil is largely a biological one, as well as dependent upon the physical, chemical and toxic condition of the surface layers. That the productivity of some soils is due to biological rather than to physical and chemical characteristics is illustrated by the attempts made to reforest Denmark. The peninsula of Jutland was covered originally by forests, but these were destroyed, until by the year 1500 the country had been transformed into a barren heath and sand dunes. At various times attempts were made to reforest these heaths but the results were disappointing until Col. E. Delgar[6] solved the problem. Spruce trees (*Picea alba, P. excelsa*), if planted alone did not thrive, but became sickly. The cause of this irregularity in the growth of spruce was thought to be local conditions of the soil, but scientific investigation of such soils did not reveal any

[3] "Ueber Assimilation freien Stickstoffs durch Schimmelpilze," *Ber. d. deutsch Bot. Ges.*, 19: 107–115, 1901.

[4] Duggar, B. M., "Fungous Diseases of Plants," p. 74; Ternetz, Charlotte, "Ueber die Assimilation des atmosphärischen Stickstoffes durch Pilze," *Jahrb. f. wiss. Bot.*, 44: 353–408.

[5] Hall, A. D., "The Soil as a Battleground," *Harper's Magazine*, October, 1910, pp. 680–687.

[6] Hovgaard, William, "The Reforestation of Denmark," *American Forestry*, XVI., 525–529, September, 1910.

difference in the physical or chemical composition of the soil. It was found, however, that the mountain pine (*Pinus montana*) acted as a nurse to spruce trees planted in its vicinity. In the same soil where spruce if planted alone would remain backward, it would if planted close to a mountain pine grow up vigorously. After some years of trial, it was found that the pine would hamper the growth of the spruce, and so it was cut down at an early age. It was discovered then that even if the mountain pine was cut down at an early age, it imparted to the adjacent spruce trees the ability to grow. The phenomenon is not understood, but it is supposed that the roots of the mountain pine are inhabited by some mycorhiza which produces the nitrogen necessary for the growth of trees and that this organism is transferred to roots of the surrounding spruce trees. Once this infection has taken place, the presence of the mountain pine is no longer necessary and it is usually cut down. Clearly this is a biological relationship.

John W. Harshberger
University of Pennsylvania

SPECIAL ARTICLES

OOSPORES OF POTATO BLIGHT

The potato blight fungus, *Phytophthora infestans*, has attracted more attention from botanists than almost any other fungus. The reasons for this are that under certain climatic conditions it causes sudden and widespread destruction of potato fields, and also that, though its life history has been carefully studied, the sexual or oospore stage has never been surely found. Berkeley, who was one of the earliest investigators to have a rational view of the cause of the epidemic of 1845, wrote at the time as follows:

> Few subjects have attracted more attention or have been more variously canvassed than the malady with which potatoes have been almost universally visited during the autumn of 1845. The press has teemed with notices the most contradictory; the attention of scientific men in every direction has been engaged by it; and three, at least, of the principal governments of Europe have issued commissions to examine into its etiology, and to discover, if possible, a remedy.

In 1875–76, at a time of considerable devastations of potato crops in Europe by the fungus, DeBary was employed by the Royal Agricultural Society of England to further investigate this fungus, while at about the same time Worthington G. Smith was engaged in similar work for the Royal Horticultural Society. As the result of their endeavors, considerable was learned concerning the life history of the fungus. Smith claimed to have found the oospores in the infested leaves and the old sets in great abundance, and was awarded a gold medal by the Royal Horticultural Society for his work. These bodies had been observed as early as 1845 by Rayer, Montagne and Berkeley. DeBary did not succeed in finding what he considered oospores of this fungus, and disputed Smith's claim with such good reasons that botanists generally believe that the oospores have never been discovered, though once or twice since investigators have claimed, without much conviction, to have found immature oogonia.

At the time of the controversy DeBary said:

> Ever since the oospores of a *Peronospora* were discovered, innumerable researches have been made for those of *Phytophthora*. I have myself looked for them for fifteen years, and on every opportunity have searched for them in the stalks, leaves, flowers, fruit and tubers of the potato. In July of the present year (1875), when the fungus appeared in this district in sad abundance, I obtained a very large amount of material for study, and at the same time secured the kindly assistance of two botanists experienced in researches of this kind, Dr. Rostafinski and Dr. Stahl. But again only negative results were arrived at. . . . That they will be regularly found somewhere or other is assured, for our knowledge of the habits of numerous allied fungi make this more than probable.

Smith deposited slides of his oospores with the British Museum. Concerning these Massee some time ago wrote me:

> I have very carefully examined W. G. Smith's type slide preparation, and am positively certain that the so-called oospores are nothing more than